Network Traffic-Based Malware Detection for Android Devices

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ITADATA, 2025

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Overview

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1. Motivations

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Android Malware Detection

- The open architecture of the Android system makes it especially vulnerable to malicious apps, posing significant threats to user privacy and security.
- Researchers continually seek innovative approaches to improve mobile malware detection methodologies.

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2. Contributions

Contributions

- We captured and analyzed mobile network traffic using TCPdump3.
- We evaluated six distinct ML models, and the XGBoost classifier was ultimately selected for its superior performance.
- We explained the predictions using SHapley Additive exPlanations (SHAP) values, Local Interpretable Model-agnostic Explanations (LIME), and Counter Factuals.
- We investigated the potential of SHAP for identifying important features and acting as a feature selection mechanism.

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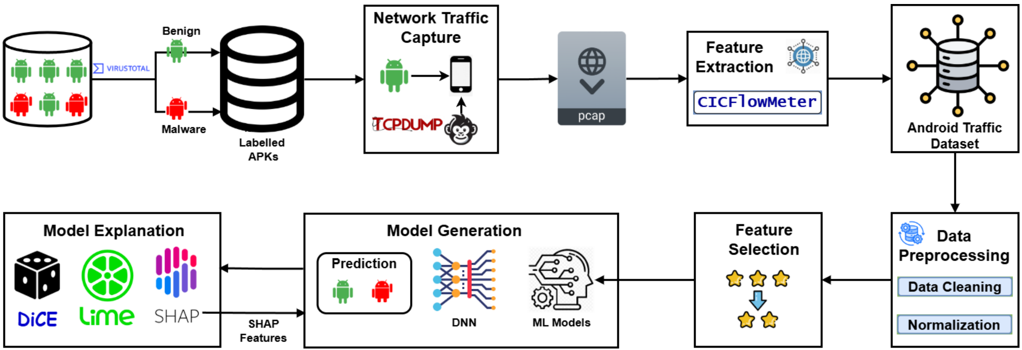
3. Proposed Approach

Proposed Approach



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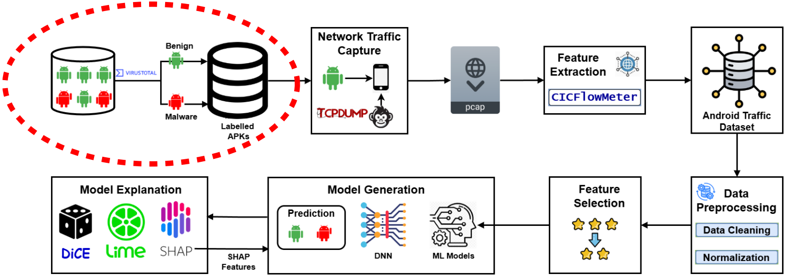
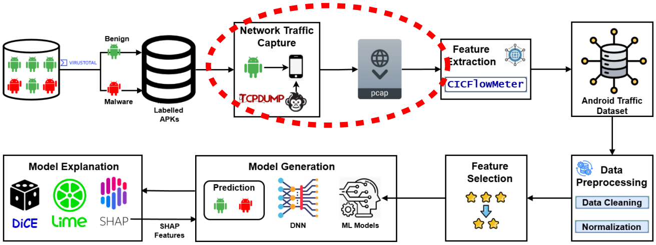
Data Collection

- Androzoo dataset comprises a diverse range of Android applications collected from various sources.
- We selected a total of 8, 819 applications from this dataset.
- To confirm whether these applications were benign or malicious, we evaluated them using VirusTotal.



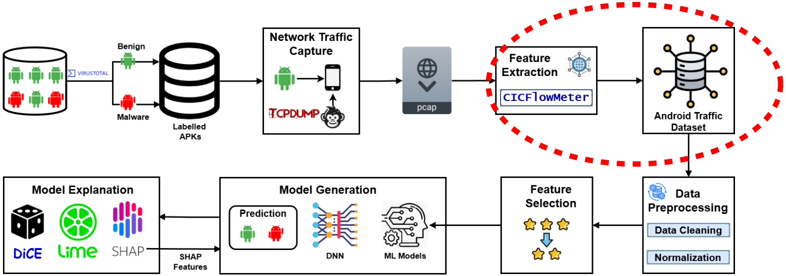
Network Traffic Capture

- We deployed APK files for installation and execution within an Android emulator.
- We employed *Tcpdump* to capture network traffic, a robust command-line packet analyzer tool designed for Linux/Unix systems.
- The Android Monkey tool is utilized to simulate random user interactions.
- Then, the network traffic generated is stored in PCAP files for detailed analysis.
- We generated a Network Traffic APK Dataset comprising 2, 980 malware samples and 5, 866 benign samples.



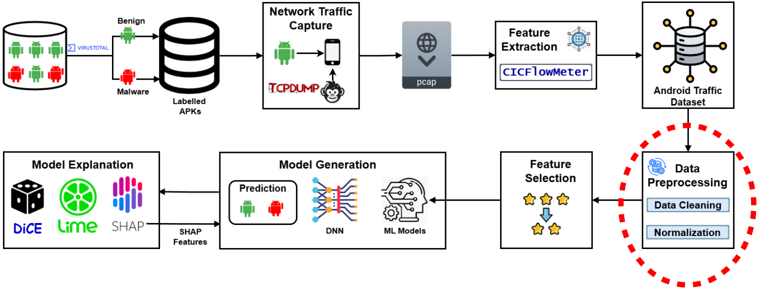
Feature Extraction

- We use *CICFlowMeter*, a portable and scalable open-source tool, to extract a total of 76 relevant features.
- These features include metrics such as flow bytes, total packets in the forward and backward directions, and the mean inter-arrival time of flows, among others.



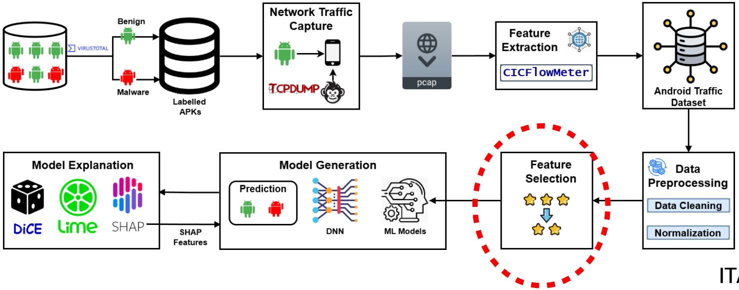
Data Preprocessing

- We identified and addressed errors, missing values, and inconsistent data, which must be corrected or removed before proceeding with the analysis.



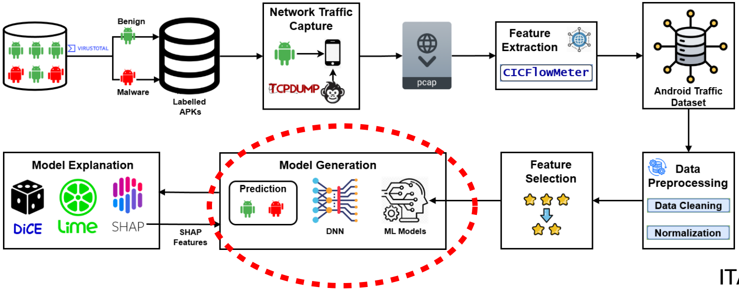
Feature Selection

- We exploited the *SelectKBest* method for feature selection, a univariate feature selection approach.
- This method selects the top *k* features based on their scores, which are computed through the ANOVA F-value, and uses f_classif as the scoring function.
- The *k* best features were calculated for various ML models, including KNN, logistic regression, SVM, decision tree, random forest, and XGBoost.



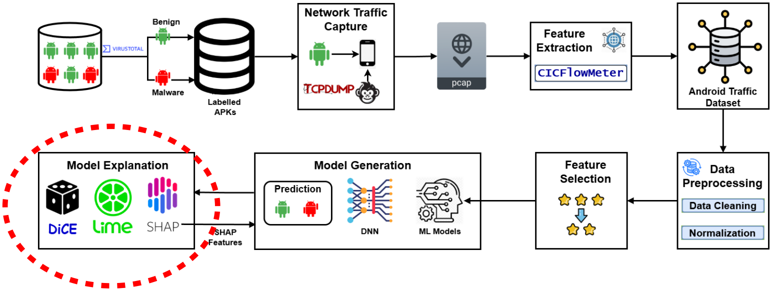
Model Generation

- We performed the *Parameter Tuning* in which we applied *RandomizedSearchCV* to tune these hyperparameters for different models: Random Forest, XGBoost, SVM, Logistic Regression, KNN, and Decision Tree.
- then, in the *Model Training*, we applied several ML and DL techniques to classify and predict malware, including Decision Trees, Random Forest, Support Vector Machines, Logistic Regression, K- Nearest neighbor, XGBoost, and DNN.



Model Explanation

- We exploited SHAP, LIME, and CounterFactuals to provide interpretability of our findings.
- Finally, we conducted an additional round of feature selection using SHAP, leveraging its ability to provide global explanations and identify the most important features contributing to predictions.



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4. Experiment Results

Comparison of ML and DL models

Model	Precision	Recall	F1-Score
Logistic Regression	0.7870	0.7732	0.7772
KNN	0.8211	0.8237	0.8184
Decision Tree	0.8527	0.8515	0.8520
SVM	0.8715	0.8656	0.8673
DNN	0.8944	0.8951	0.8938
Random Forest	0.9087	0.9093	0.9085
XGBoost	**0.9323**	**0.9325**	**0.9323**

Table: Performance Comparison of Android Malware Detection Models using network traffic

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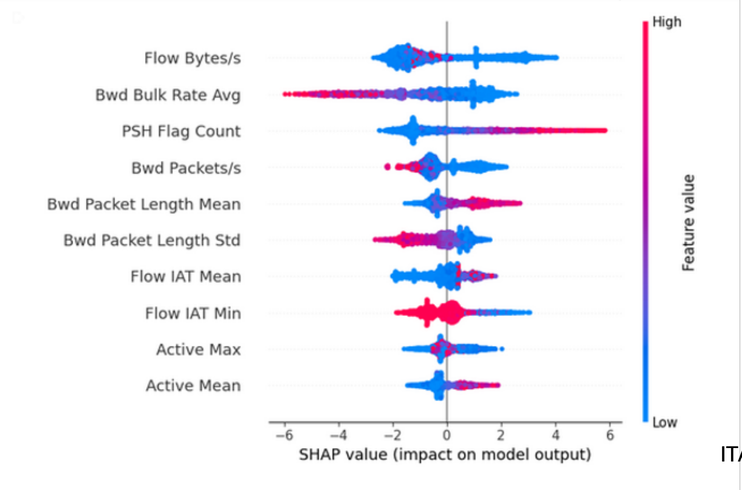
Correlation between specific features and the prediction outcome for Android malware detection.



Lime Explanation

Features `Packet Length Variance`, `Bwd Packet Length Std`, `Flow packets` and `Fwd Packets Length Std` contribute more to the Benign class.

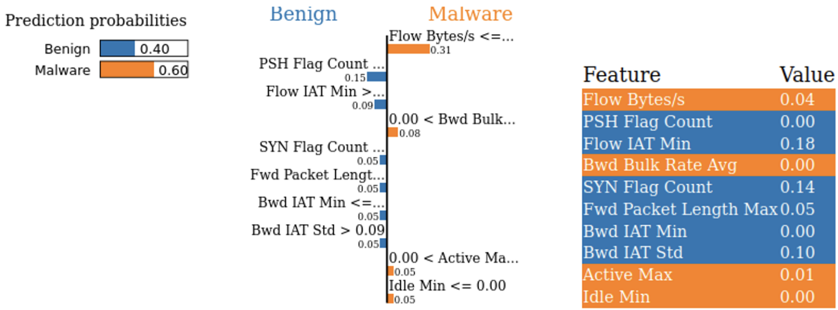


Figure: Lime explanation of Malware class

Frame Title

Features `Flow Bytes`, `Bwd Bulk Rate Avg`, `Active Max`, and `Idle Min` contribute more to the Malware class.

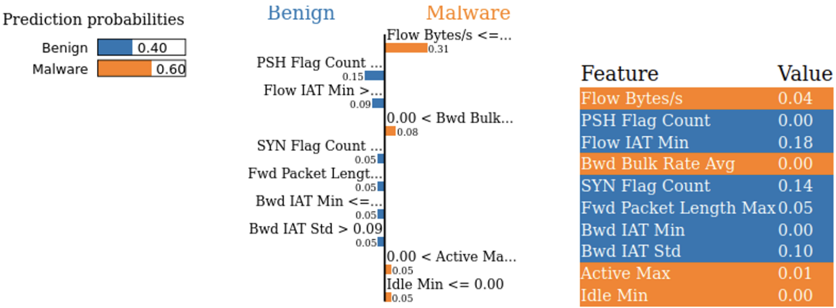


Figure: Lime explanation of Malware class

Feature selection based on the SHAP approach

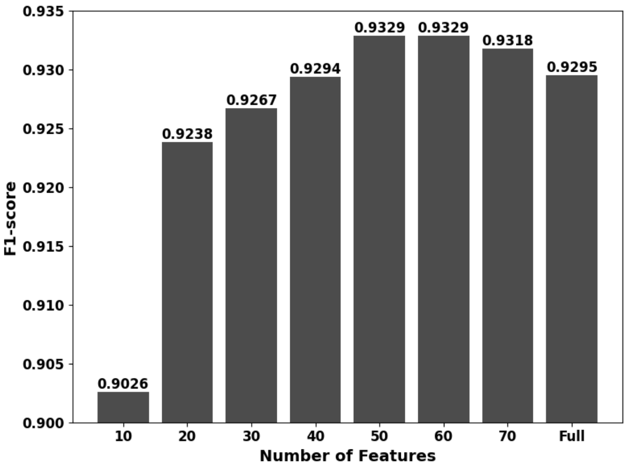


Figure: F1-scores of the models using the SHAP-based features

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5. Conclusion and Future Work

Conclusion and Future Work

- We collected a dataset of malicious and benign APKs to study the behavior of Android malware.
- By applying several ML and DL techniques, we made significant strides in classifying APKs based on network traffic.
- Our experiments demonstrated that the XGBoost classifier outperformed other algorithms, achieving an impressive weighted F1-score of 93.23% for network traffic analysis.
- We also provide an explainer to help interpret the model.
- Our findings contribute to the advancement of security solutions aimed at reducing the risks associated with Android malware.
- In the future, we plan to integrate additional features such as dynamic analysis and permissions-based data from APKs.

Thanks for the attention!

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